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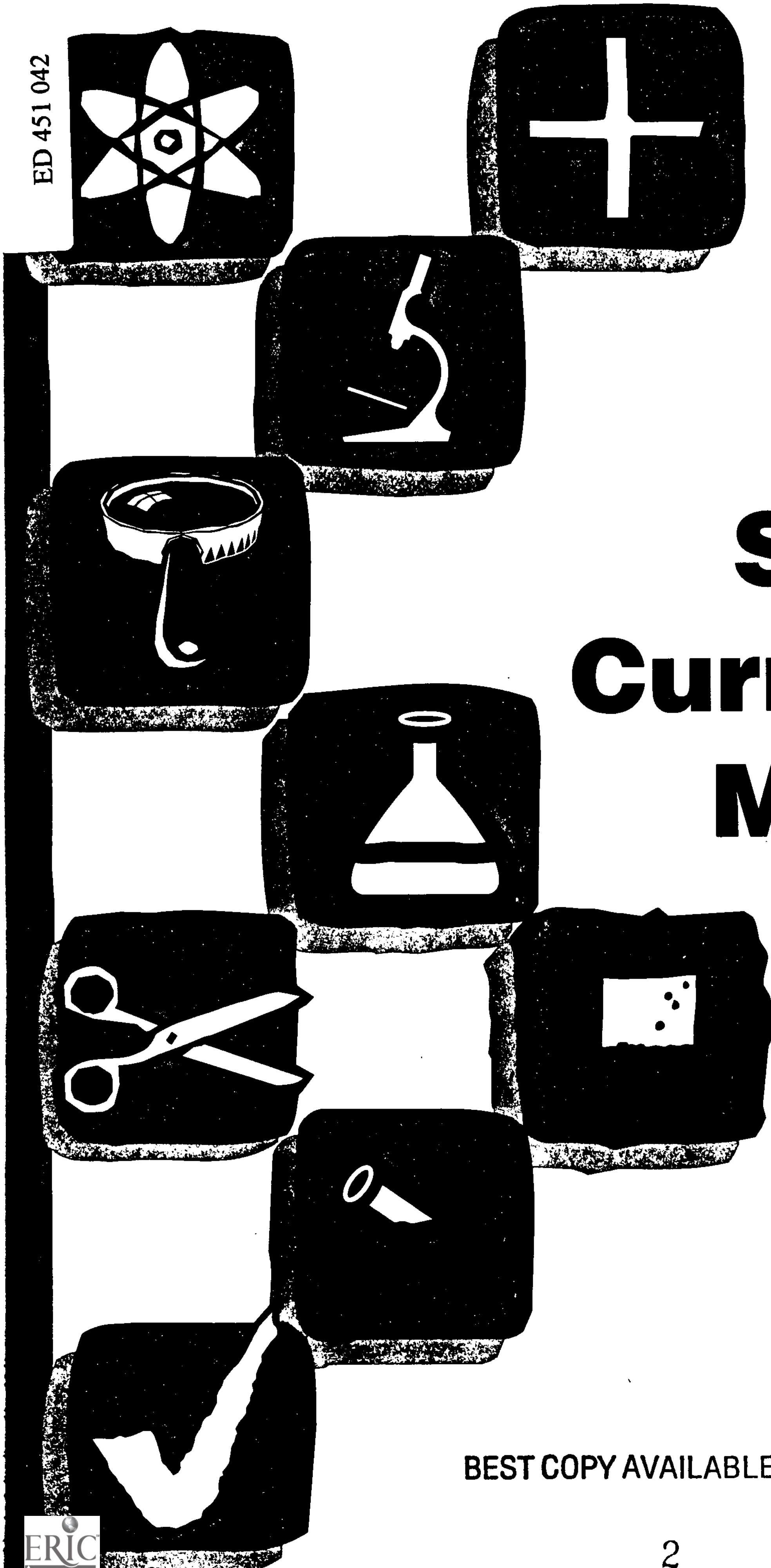
ABSTRACT

This workbook introduces curriculum mapping, a process used by schools and districts to reform and improve curricula. The school's or district's elementary and middle level science curriculum can be mapped out by indicating what topics are taught at what grade levels. This workbook is part of the North Central Regional Educational Laboratory's (NCREL's) ongoing effort to develop accessible and user-friendly, data-driven decision making tools. The workbook allows for the analysis and comparison of individual science curriculum to the United States as a whole and to top achieving nations around the globe. The curriculum is first mapped out on a tally sheet by indicating what topics are taught at which grades, then a plot is made of tally sheet totals on a variety of templates showing comparable data from the United States and top achieving nations. (SAH)



Science Curriculum Mapping

Workbook

NCREL
North Central Regional Educational Laboratory
"Applying Research and Technology to Learning"

Curriculum Mapping Workbook

This workbook introduces "curriculum mapping," a process used by schools and districts to reform and improve curricula. With this workbook, you can "map out" your school or district's elementary and middle-level science curriculum (Grades 1-8) by indicating what topics are taught at which grade level.

A Web-based version of this tool is available for more advanced analysis in both mathematics and science. With the Web-based version, rich international mathematics and science curriculum maps from top-achieving nations are available for comparison to your local curricula.

Background

Today, the U.S. educational system faces a myriad of challenges to initiate and implement curriculum reform. Results from the Third International Mathematics and Science Study (TIMSS), the most extensive study of international achievement to date, provide overwhelming evidence that topics in U.S. curricula are too numerous and retained too long. Unfortunately, district administrators lack user-friendly methods to make informed decisions about curricula.

The North Central Regional Educational Laboratory (NCREL), in partnership with the U.S. TIMSS National Research Center at Michigan State University, has responded by developing tools to facilitate more comprehensive mapping and analysis of curricula.[1] This introductory workbook and the accompanying Web site are designed to help schools and districts reform their mathematics and science curricula. These products are part of NCREL's ongoing effort to develop accessible and user-friendly data-driven decision-making tools.

How It Works

This workbook allows you to analyze and compare your science curriculum to the U.S. as a whole and to top-achieving nations around the globe. You begin by "mapping out" your curriculum on your tally sheet by indicating what topics are taught at which grades (K-8). Then, you plot your tally sheet totals on a variety of templates—or displays—showing comparable data from the U.S. and top-achieving nations. These comparisons will help you make informed decisions about curriculum reform strategies.

For more sophisticated curriculum analysis, use our Web site (www.ncrel.org/currmap) to map your science curriculum. Web users are guided through a series of analyses, complete with graphic displays that superimpose their curricula against that of top-achieving TIMSS nations.

Before You Start

Quality curriculum analysis and evaluation is a time-consuming task. We recommend that you allow 1-2 hours for the mapping process. Effective curriculum mapping also requires the right personnel. We suggest that you bring together the following personnel and documentation:

- District-level staff knowledgeable of your standardized elementary science curriculum (The standardized curriculum appears in your district textbooks and/or your district curriculum guide.)
- Science curriculum guides developed for your district
- Other personnel and written material that influence what is taught at what grade level(s)

Refer to the Pullout Section for Instructions on Completing Your Tally Sheet

[1] The TIMSS curriculum frameworks used in these products were developed by the Survey of Mathematics and Science Opportunities (SMSO) research project, funded by the U.S. Department of Education and the National Science Foundation. References include:

Survey of Mathematics and Science Opportunities. (1992). *Science curriculum framework* (Research Report Series 37). East Lansing, MI: Michigan State University.

Survey of Mathematics and Science Opportunities. (1992). *Mathematics curriculum framework* (Research Report Series 38). East Lansing, MI: Michigan State University.

Robitaille, D. F., Schmidt, W. H., Raizen, S., McKnight, C., Britton, E., & Nicol, C. (1993). *Curriculum frameworks for mathematics and science* (TIMSS Monograph No. 1). Vancouver: Pacific Educational Press.

Instructions for Mapping Your Science Curriculum

To complete your Tally Sheet for Science Curriculum, read the description for each topic (in this instruction booklet) and decide for each grade level whether the topic is:

- **Not Taught (leave the box on the tally sheet blank).** A topic is not taught if ANY of the following statements are true:
    - The topic is not taught at that grade in your school or district.
    - The grade level is not included in your school or district.
    - The curriculum includes ONLY incidental coverage of the topic.

  Note: Avoid using "Not Taught" as a substitute for "I don't know."

- **Taught (write a "1" in the box on the tally sheet).** A topic is taught if at least one lesson addresses the topic. This category does not include incidental coverage of a topic.
- **Emphasized (write a "2" in the box on the tally sheet).** A topic is emphasized if several lessons are devoted to teaching the topic.

In the example below, the topic "Composition" is taught (1) in first grade, and it is emphasized (2) in Grades 2, 3, and 4. The topic is not taught in Grades 5-8.

Topic	1	2	3	4	5	6	7	8	Total Grades per Topic
Composition	1	2	2	2					4

Special Instructions for Mapping Middle School Curricula

In instances where a district has specialized tracks of study in middle school, separate curriculum maps should be completed to describe each intended science curriculum.

Science Topic Descriptions

Earth sciences

Earth features

✓ Composition—earth's crust, mantle, and core; distribution of metals, minerals

✓ Landforms—mountains, valleys, continents

✓ Bodies of water—oceans, lakes, ponds, bottom of ocean, rivers

✓ Atmosphere—layers of atmosphere (ionosphere, stratosphere, etc.)

✓ Rocks, soil—soil types, soil formation, pH of soil, classes of rocks, specific rocks and their uses

✓ Ice forms—glaciers, icebergs, Antarctic

Earth processes

✓ Weather and climate—weather maps, weather forecasts, hurricanes, seasons of the year

✓ Physical cycles—rock cycle, water cycle

✓ Building and breaking—plate tectonics, earthquakes, volcanoes

✓ Earth's history—geologic timetable, formation of fossils, fossil fuels, and mineral resources

NOTE: This form is a modified version of the GTTM developed for the Third International Mathematics and Science Study (TIMSS) of 1995.

Earth in the universe

- ✓ Earth in the solar system—earth/sun/moon system, night/day, tides, north/south hemisphere, seasons
- ✓ Planets in the solar system—planets' features, order of planets in the solar system
- ✓ Beyond the solar system—galaxies, black holes, quasars, types of stars, constellations of stars
- ✓ Evolution of the universe—origin/history/future of the universe

Life sciences

Diversity, organization, and structure of living things

- ✓ Plants, fungi—types of plants and fungi
- ✓ Animals—types of animals
- ✓ Other organisms—types of microorganisms
- ✓ Organs, tissues—circulatory systems, plant leaf, systems for movement, eyes, ears
- ✓ Cells—cell membranes, nucleus, mitochondria, vacuoles

Life processes and systems enabling life functions

- ✓ Energy handling—energy capture, storage, and transformation: photosynthesis, respiration, biosynthesis (protein, carbohydrate, fat, etc.), digestion, excretion
- ✓ Sensing and responding—biofeedback in systems, homeostasis, sensory systems, responses to stimuli (e.g., nervous system and brain)
- ✓ Biochemical processes in cells—regulation of cell functions, translation, protein synthesis, enzymes

Life spirals, genetic continuity, diversity

- ✓ Life cycles—life cycles of plants, insects, etc.: growth, development, reproduction, dispersal, aging, death; cell division; cell differentiation
- ✓ Reproduction—plant/animal reproduction, asexual/sexual reproduction
- ✓ Variation and inheritance—Mendelian/non-Mendelian genetics, quantitative inheritance, population genetics
- ✓ Evolution, speciation, diversity—evidence for evolution, effects of evolution, processes of evolution (e.g., adaptation, natural selection), nature of a species, domestication, importance of diversity
- ✓ Biochemistry of genetics—concept of the gene, DNA/RNA, gene expression, genetic engineering

Interactions of living things

- ✓ Biomes and ecosystems—tundra, rain forest, savannah, wetlands, tide pools
- ✓ Habitats and niches—habitats of endangered species, niches of species
- ✓ Interdependence of life—food webs/chains, symbiotic relationships, impact of humans
- ✓ Animal behavior—migration of birds, mate selection, rearing of young, social groupings of animals (e.g., beehives, elephant herds)

Human biology and health

- ✓ Human biology
- ✓ Nutrition—vitamins and minerals in diet
- ✓ Disease—disease types, causes, prevention

Physical sciences

Matter

- ✓ Classification of matter—homogeneous and heterogeneous materials, elements, compounds, mixtures, solutions

✓ Physical properties—weight, mass, states of matter, malleability of metals, hardness, shape

✓ Chemical properties—periodic table, acidity, reactivity, atomic spectra, organic/inorganic

Structure of matter

✓ Atoms, ions, molecules—atoms, ions, molecules as the basis for different substances

✓ Macromolecules, crystals—polymers, shape/function of biological molecules, crystal structure

✓ Subatomic particles—electrons, protons, neutrons

Energy and physical processes

✓ Energy types, sources, conversions—potential and kinetic; chemical, nuclear, fossil fuels; hydroelectric power; changing one form of energy to another; energy and work, efficiency

✓ Heat and temperature—temperature scales, heat as a form of energy, heat versus temperature

✓ Wave phenomena—wave properties, types (e.g., IR, UV), wave interactions

✓ Sound and vibration—transmission of sound, acoustics, harmonics

✓ Light—nature of light, optics, luminosity, reflection, refraction

✓ Electricity—static electricity, electrical fields, alternating/direct current, electrical circuits

✓ Magnetism—magnets and their magnetic fields, magnetic properties

Physical transformations

✓ Physical changes—gas laws, changes in states of matter, mixing

✓ Explanations of physical changes—general explanations for boiling, freezing, dissolving, etc.

✓ Kinetic theory—kinetic molecular theory

✓ Quantum theory and fundamental particles—quantum nature of light, photoelectric effect

Chemical transformations

✓ Chemical changes—definition of chemical change, types of reactions (e.g., displacement, acid-base, oxidation-reduction, etc.)

✓ Explanations of chemical changes—ionic/covalent bonding, electron configurations, electronegativity

✓ Rate of change and equilibria—reagent concentrations, reaction conditions, dynamic equilibrium

✓ Energy and chemical change—activation energy, exothermic and endothermic reactions

✓ Organic and biochemical changes—types of organic compounds, organic reactions, biochemistry

✓ Nuclear chemistry—fission, fusion, isotopes, half-life, mass/energy conversion

✓ Electrochemistry—electrochemical cells/batteries, electrolysis, oxidation-reduction reactions

Forces and motion

✓ Types of forces—gravitational force, friction, centripetal force

✓ Time, space, and motion—measurement of time, types of motion (linear, rotational), describing motion (constant velocity, acceleration, momentum), reference frames for motion

✓ Dynamics of motion—balanced and unbalanced forces, action/reaction, momentum and collisions

✓ Relativity theory—mass/energy/velocity relationship, explaining the velocity of light, time frames while traveling at the speed of light

✓ Fluid behavior—hydraulics, Bernoulli principle, pneumatics

Science, technology, and mathematics

✓ Nature or conception of technology—identifying needs and opportunities, generating a design, planning and making, evaluating

Interactions of science, mathematics, and technology

- ✓ Influence of mathematics, technology in science—information about contributions of mathematics and technology to the development of scientific thought and the practice of science (e.g., new mathematics and technology make it possible for science to investigate new questions or to analyze data in new ways)
- ✓ Applications of science in mathematics, technology—information about contributions of science to the development and practice of mathematics and technology (e.g., development of calculus and classical mechanics, industrial processes, types of simple machines, measuring devices [thermometer, Geiger counter])

Interactions of science, technology, and society

- ✓ Influence of science, technology on society—social, economic, ethical impacts of scientific and technological advances (e.g., the influence of scientific ideas on social thought, such as social Darwinism; the effects of computers on lifestyles)
- ✓ Influence of society on science, technology—information about the influence of society on the directions and progress of science and technology (e.g., controversies over research in genetic engineering, use of animals in research)

✓ **History of science and technology—**famous scientists, classic experiments, historical development of scientific ideas, industrial revolution, classic inventions

Environmental and resource issues related to science

- ✓ Pollution—acid rain, thermal pollution, global warming
- ✓ Conservation of land, water, and sea resources—rain forest, old growth forests, water supplies
- ✓ Conservation of material and energy resources—fossil fuels versus alternative energy sources, recycling aluminum
- ✓ World population—population statistics, trends; effects of increasing world populations (e.g., world hunger, epidemic diseases)
- ✓ Food production, storage—agricultural methods, food supply and demand, distribution methods
- ✓ Effects of natural disasters—environmental damage of hurricanes/typhoons, volcanoes, drought

Nature of science

- ✓ Nature of scientific knowledge—scientific methods, knowledge subject to verification, knowledge subject to change
- ✓ The scientific enterprise—canons of ethics and decision making, professional communication, the scientific community, personnel and processes in large-scale research efforts

Science and other disciplines

- ✓ Science and mathematics—explicit mathematics instruction in the science curriculum
- ✓ Science and other disciplines—science curriculum incorporated with language arts, social studies, or the arts; examples include chemistry of painting, using art or music to represent or illustrate science concepts, studying the role of science in other cultures, writing stories as metaphors that illustrate science concepts

Breadth of Curriculum

Breadth of curriculum is defined as the number of topics taught or intended at each grade level. Analysis of breadth gives you a first look at your curriculum. It does not tell you what, when, or how long topics are taught, but rather it provides a general sense of the number of topics at each grade. Analysis of breadth is important because of the implications it can have for depth of instruction. Given the limited number of instructional hours in a school year, greater breadth implies less depth of instruction. In the case of breadth, *more is not better*.

You might pose the following questions to your school or district improvement team to generate discussion about curriculum breadth:

- Are we comfortable with the total number of topics intended at each grade level? Do we think there are too many? not enough?
- Is the breadth of the curriculum so great that it is compromising depth of content coverage?
- Can we eliminate topics at any grade level?
- Is the breadth of our curriculum similar to that of the United States? of top-achieving TIMSS nations?
- Does the breadth of the curriculum increase from the elementary to middle grades? Are topics accumulating?

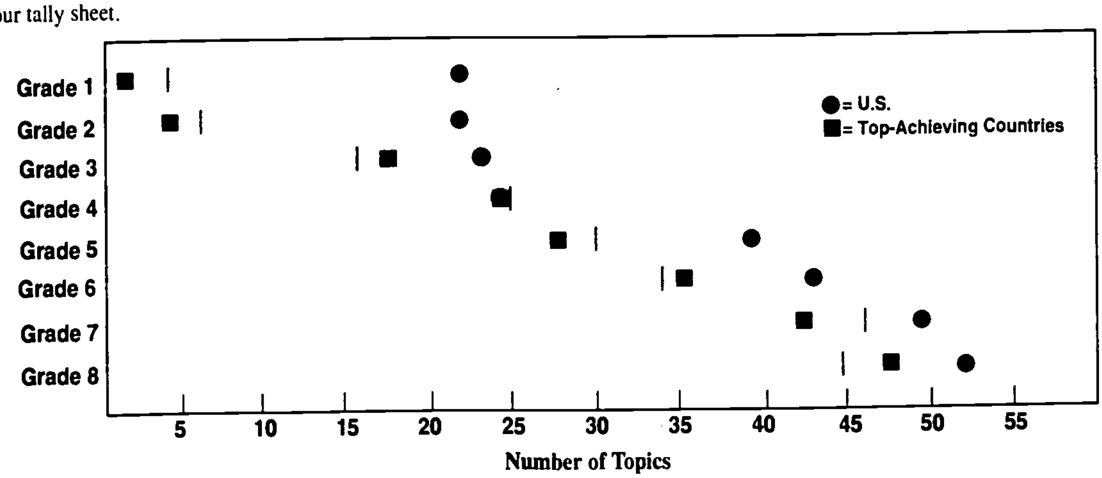
Results from TIMSS revealed substantial breadth in the U.S. curriculum when compared to the 40 nations participating in the study. One way to determine whether your school or district has excess breadth in its curriculum is to hand-plot the curriculum against the international distribution. On the display below, plot the "Total Topics per Grade" from your tally sheet with an "X" for each grade level. If your "X" is to the right of the gray bar for any grade, you are including more topics than 75 percent of the TIMSS nations for that grade. Therefore, you may want to evaluate the scope and sequence of your curriculum. Always refer to your state standards when considering reform.

The display below offers only a cursory look at the breadth of your curriculum. More advanced comparative displays can be generated from the Web site (www.ncrel.org/currmap). These advanced displays provide a wealth of information to guide data-driven curriculum reform.

Display 1: Number of Intended Science Topics

The U.S. composite for each grade is indicated with a circle. A composite for the top-achieving nations for each grade is indicated with a square. The gray bar shows how many science topics were intended at each grade level for all TIMSS countries, from the 25th percentile to the 75th percentile. The red line indicates the median number of topics at each grade level.

Directions: With an "X," plot the number of intended topics for your curriculum using the "Total Topic per Grade" at the bottom of your tally sheet.



Source: Schmidt, W. H., McKnight, C. C., & Raizen, S. A. (1997). *A splintered vision*. The Netherlands: Kluwer.

Tally Sheet for Science Curriculum

Topic	1	2	3	4	5	6	7	8	Total Grades per Topic*
Earth sciences									
Composition									
Landforms									
Bodies of water									
Atmosphere									
Rocks, soil									
Ice forms									
Weather and climate									
Physical cycles									
Building and breaking									
Earth's history									
Earth in the solar system									
Planets in the solar system									
Beyond the solar system									
Evolution of the universe									
Life sciences									
Plants, fungi									
Animals									
Other organisms									
Organs, tissues									
Cells									
Energy handling									
Sensing and responding									
Biochemical processes in cells									
Life cycles									
Reproduction									
Variation and inheritance									
Evolution, speciation, diversity									
Biochemistry of genetics									
Biomes and ecosystems									
Habitats and niches									
Interdependence of life									
Animal behavior									
Human biology									
Nutrition									
Disease									
Physical sciences									
Classification of matter									
Physical properties									
Chemical properties									
Atoms, ions, molecules									
Macromolecules, crystals									
Subatomic particles									
Energy types, sources, conversions									
Heat and temperature									
Wave phenomena									
Sound and vibration									
Light									
Electricity									
Magnetism									
Physical changes									
Explanations of physical changes									
Kinetic theory									

*Indicate total number of grades a topic appears in your curriculum. If a topic is not in your curriculum, put an "X" in the box.

Turn the page to continue

Tally Sheet for Science Curriculum (continued)

*Indicate total number of grades a topic appears in your curriculum. If a topic is not in your curriculum, put an "X" in the box.

Topic	1	2	3	4	5	6	7	8	Total Grades per Topic*
Physical sciences *(continued)*									
Quantum theory and fundamental particles									
Chemical changes									
Explanations of chemical changes									
Rate of change and equilibria									
Energy and chemical change									
Organic and biochemical changes									
Nuclear chemistry									
Electrochemistry									
Types of forces									
Time, space, and motion									
Dynamics of motion									
Relativity theory									
Fluid behavior									
Science, technology, and mathematics									
Nature or conceptions of technology									
Influence of mathematics, technology in science									
Applications of science in mathematics, technology									
Influence of science, technology on society									
Influence of society on science, technology									
History of science and technology									
Environmental and resource issues									
Pollution									
Conservation of land, water, and sea resources									
Conservation of material and energy resources									
World population									
Food production, storage									
Effects of natural disasters									
Nature of science									
Nature of scientific knowledge									
The scientific enterprise									
Science and other disciplines									
Science and mathematics									
Science and other disciplines									
Total Topics per Grade (1s and 2s)									= A**
Total Topics in Curriculum									B***

**Sum total of all topics in Grades 1-8

***Number of boxes in "Total Grade" column *without* an "X"

Topic Duration

Duration of topic is the length of time (number of grades) a topic is retained in a curriculum. Duration of topic has a direct relationship to breadth of curriculum. For example, curricular material is often recycled, reinforced, or re-introduced rather than dropped from the curriculum, increasing the breadth of the curriculum at each successive grade level. As a result, more advanced topics may be crowded out or not covered in depth, reducing the rigor of the curriculum.

You might pose the following questions to your school or district improvement team to generate discussion about duration of topics:

- Are topics retained in the curriculum too long?
- How does the duration of topics reflect teachers' expectations of students' ability to master material at any grade level?
- Are we retaining topics in the curriculum after they are taught? after they are mastered?
- Do state standards require a high or low duration of certain topics? Or is topic duration a direct result of the way we designed the curriculum?

Use the Duration Worksheet below to compare your school or district's average topic duration to that of top-achieving TIMSS nations.

Duration Worksheet

From your tally sheet...

1. Enter the sum total of all topics in Grades 1-8 (box A): ___________
2. Enter the number of boxes in the "Total Grade" column without an "X" (box B): ___________

Calculation 1: Average Topic Duration

Box A ÷ Box B = Average Duration

$\boxed{} \div \boxed{} = \boxed{}$

Calculation 2: How Do You Compare With Top-Achieving Nations?

Your Average Duration (calculation 1) – Average Duration for Top-Achieving Nations = Length of Your Bar

$\boxed{} - \boxed{3.94} = \boxed{}$

About NCREL

The North Central Regional Educational Laboratory (NCREL) is a not-for-profit organization dedicated to helping schools—and the children they serve—reach their full potential. One of ten regional educational laboratories, NCREL serves a seven-state region of the Midwest: Illinois, Indiana, Iowa, Michigan, Minnesota, Ohio, and Wisconsin.

NCREL's vision is for effective educational systems in which all students are successful learners. Our mission is to improve the performance of all parts and levels of the K-12 educational system from the classroom to the state.

NCREL also operates the North Central Mathematics and Science Consortium (NCMSC) and the North Central Regional Technology in Education Consortium (NCRTEC).

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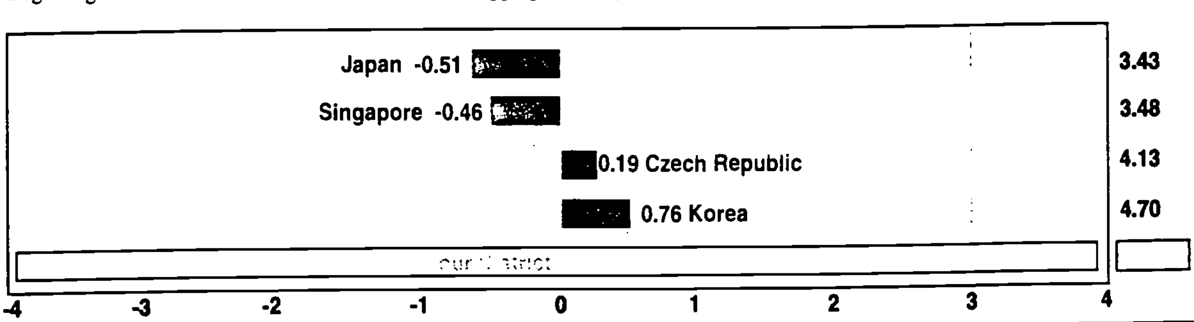
Display 2: Average Duration of Science Topics Relative to Top-Achieving Nations

The anchor, or zero mark, for this display is the average duration (3.94 grades) for four TIMSS nations that significantly outperformed most other nations around the world in Grade 8 science achievement. The individual average duration for each of the four nations is provided to the right of the display. The length of the bars indicates how much more or less topics are retained in a nation's science curriculum compared to the composite average. For example, on average, science topics are retained in Korea's curriculum 4.70 grades, which is .76 grades more than the composite average of 3.94. Therefore, Korea's bar is .76.

Directions: Write the average duration of topics in your curriculum (calculation 1) in the box in the lower right corner of the display. Beginning with the anchor, or zero mark, shade in the appropriate length of your bar (calculation 2).



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